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Industrial Manganese Ores of the USSR

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I. CHEMICAL REQUIREMENTS FROM ORES

The constant utilization of manganese in the production of steel is due to its exceptional qualities. In the first place, manganese, as an active de-oxidizer, extracts from the melt all the oxygen, eliminates from the steel iron oxides, and contributes production of sound pigs. In addition, manganese is an excellent desulfurizer as it extracts from the melt all the sulfur which even when present in insignificant amounts (0.02 percent) is one of the causes of steel brittling and breaking when heated red-hot. Finally, manganese is of primary importance as an alloy constituent and can replace, in a number of cases, more expensive and rare metals in the production of high grade steels. Even an insignificant addition of it to steel sharply increases its mechanical properties such as hardness, forging, toughness, and resistance to wear, playing a tremendous part in the production of rollings, band, punchings, in the production of rust-resistant, heat-resistant, structural and other grades of steel. In other words, without manganese the highly developed steel casting industry cannot exist, particularly since all attempts to find a readily available and cheap substitute have not yet been successful.

Depending on their quality, particularly their chemical composition, manganese ores utilized in the ferrous metallurgy are used for the following purposes:

1. High grade manganese ores, poor in iron and phosphorus content, are used in blast furnaces and electric furnaces to produce standard grades of ferro-manganese which is used as an addition agent in the production of special grades of steel.

Silico-manganese, which is important in the manufacture of certain grades of steel, is also produced in insignificant quantities.

2. Iron-manganese ores, depending on their manganese to iron ratio, are used for the production of non-standard grades of ferro-manganese, popularly known as Spiegel, and silicospiegel. All of these ferrous alloys are substitutes for the high-grade alloys of ferro-manganese used in the manufacture of ordinary and common grades of steel.

3. Iron-manganese ores, relatively free of phosphorus, are used in the production of manganese pigs (with a manganese content of 5 to 10 percent) which are utilized as additions for the re-carburization and preliminary de-oxidation of steel in order to decrease the amount of ferro-manganese used for this purpose.

4. Siliceous ores, poor in manganese and iron, not suitable for the production of the above named special ferrous alloys, may be used only as a charge in the production of ordinary pig iron from iron ores, which contain little or no manganese. Green, rich in manganese slag, obtained during the production of ferro-manganese may also be used successfully for this purpose.

5. On the other hand, as tests have shown, calcium ores, poor in manganese and iron, are very valuable raw material being utilized as basic manganese fluxes in the production of steel in Martin furnaces. In a number of cases, these ores may replace to an appreciable degree the expensive ferro-manganese used in the production of common grades of steel.

6. Finally, it should be pointed out that ores rich in man-

ganese are used in a raw form in the production of steel, being added at the last stage of production to increase the manganese content in the refined metal. The most desirable ores for this purpose are self-fluxing ores, namely, those containing important quantities of calcium oxide and magnesium oxide (type of ore originating in the Sapalsk area).

Besides the indicated purposes, manganese is used in the preparation of special rustproof and heat resistant manganese steels, Godfield steels, structural and other steels.

In the non-ferrous metallurgy, alloys of manganese and copper are of the greatest importance in the manufacture of corrosion-resistant metal reservoirs, ship propellers, other alloys with aluminum for the aviation industry, alloys of copper with manganese and nickel having great electrical resistance, and others.

The specifications of manganese ores for the production of ferro-manganese as well as for other alloys are dictated primarily by metallurgical considerations of which the most important are summed up as follows:

1. While iron in the presence of manganese oxides is almost completely reduced during melting, the reduction of manganese varies from 75 to 50 percent. (The reduction process of manganese oxides to metal is accomplished in the lower part of the blast furnace (behind the boshes). As the coke burns and settles down, the higher oxides gradually pass into a combination of lower oxides ($MnO_2 \rightarrow Mn_2O_3 \rightarrow Mn_3O_4 \rightarrow MnO$). A part of manganese oxide combined with silica, forms a silicate melt as may be seen from a microscopic study of slags (in particular, the formation of tephroite Mn_2SiO_4

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and others). In a reaction with calcium, with the formation of calcium silicates, the manganese is reduced to the metallic state. However, in the smelting of rich ores, poor in silica, the main mass of manganese is reduced apparently with the aid of carbon oxide (CO) and manganese oxide, which may also be noted under the microscope in tephroite slags in the form of mineral manganosite (MnO) while in the case of poorer ores the reduction declines to 40-35 percent, depending on the quality of the raw material (chiefly on the silica content of the ores and the correlation of slag forming components in the charge), on the smelting conditions necessary to obtain a certain grade of ferro alloys, and on a series of other causes. Only in smelting silico spiegel and siliceous manganese rich in silica, that is, in converting appreciable quantities of siliceous ore into pig iron, does the degree of reduction reach 80 to 95 percent.

Thus, in the production of manganese alloys with iron and small quantities of silicon, the manganese losses reach 25 to 65 percent (without taking into account the loss of small particles if the blast is strong).

2. These losses are as follows:

In slags, where 7 to 20 percent or more of the entire manganese put in the charge, depending on the quantity of the slag, appears in the form of manganese silicates.

Losses in the form of volatile manganese oxides leaving the furnace with the escaping gases at high temperatures at the rate of 12 to 20 percent or more depending on the melting temperature (The melting temperatures of ferromanganese and spiegel are between 1600 and 1700 degrees; the melting of ordinary pigs is carried out at temperatures from 1350 to 1500 degrees) particularly when melting in electric furnaces, and finally,

Losses in the form of dust and small ore particles during hard blowing. Depending on the content of dust and small particles content of the ore and on the degree of friability, or rather on the ability of the ore to withstand crushing and pulverization in the process of moving the charge in the blast furnace, these losses may vary from 5 to 10 percent and sometimes reach 30 percent (for small grain ores). A more accurate picture of manganese losses of the first 2 types may be obtained from the following data (Table 5).

TABLE 5

LOSSES IN MANGANESE DURING SMELTING OF SPECIAL AND COMMON PIG IRON

(in Percent)

Product	Volatilize	Absorbed by pigs	Absorbed by slags
Ferromanganese	10	75-80	10-15
Spiegel	5	75-80	15-20
Foundry pig iron	0	70-75	25-30
Bessemer pig iron	0	60-70	30-40
Martin and Thomas Converter pig iron	0	50-60	40-50
Foundry and converted pig iron on charcoal	0	40-50	50-20

3. The presence of large quantities of silica with a low content of alkaline earths compels to add to the charge appreciable quantities of limestone in order to flux the silica and aluminum oxide as well as to create the most favorable conditions for the reduction of manganese. Consequently, the smelting of ores richer in silica even with coke rich in ashes will result in obtaining large

quantities of slag with a great loss of manganese and conversely with a lower extraction of metal under an unfavorable ratio of manganese to iron. For example, calculations indicate that from ore containing 40 percent manganese and 25 percent silica it is possible to obtain almost twice as much metal as from ore containing 30 percent manganese and 35 percent silica although the manganese content decreased by one quarter only. It is clear from this that it is not possible to smelt high grade manganese alloys from ores very rich in silica.

From this point of view it is absolutely inadvisable to mix rich ores (with a 40-45 percent manganese content) with poor ores containing 20-25 percent manganese, as is the practice in some mines, for increasing the weight of ores delivered to the plant. It is fully clear that such measures, based on lack of knowledge, are very harmful.

In addition, the metallurgical practice also shows that in order to combat large losses of manganese in slags, it is necessary to observe the following conditions: (1) increase the basicity of the slag by increasing the amounts of calcium oxide and magnesium oxide, and (2) heat the blast to a maximum temperature (not under 800 degrees) and increase the amount of coke while maintaining the hottest temperature in the furnace, which may be controlled by observing the silicon content of the metal.

Fully satisfactory smelting results are achieved with slag having a ratio of $SiO_2/CaO = 0.8$ to 0.9. For ores containing appreciable quantities of manganese (above 10 percent) this ratio may be reduced even to 0.7 since manganese ores have a greater fluidity than the purely calcareous ores.

4. The amount of manganese and iron in the obtained melt represents 90 percent, the remainder is carbon (up to 5 to 7 percent) silicon and phosphorus. In the process, because of its almost complete oxidization, the iron content increases 2 to 4 times (while there is a simultaneous important loss in manganese) as compared with the original content in the ore (depending on how rich the ore is in manganese).

This is easily demonstrated by the following simple calculation. (The material balance calculations for blast furnace charges for a given final product involve complicated mathematical and graphic methods.) Suppose we have a richer ore in lumps containing 50 percent manganese and 5 percent iron. Assuming the rate of reduction of manganese to be 75 percent and the amount of iron and manganese in the pig iron to be 90 percent, the calculation will show approximately the following composition of ferromanganese: Mn about 80 percent and Fe about 10.5 percent (that is more than twice as much as compared with the initial content in the ore).

It is clear from this that in order to produce high quality grades of ferromanganese the iron content of the ores must be at a minimum. The ratio of manganese to iron in the rich ores should not be lower than 7. In extreme cases it can be reduced to 6 (provided the blast furnace is in excellent working order).

5. In the smelting of special grades of ferromanganese from manganese ores, extreme attention must be paid to the phosphorus content which is considered as a harmful ingredient. Phosphorus, as well as iron, during the smelting process pass into ferro alloys if not completely at least in the amount of 95-75 percent of the original ore content. During the smelting of steel, when ferro-

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manganese is added, the phosphorus is almost completely absorbed. Inasmuch as the ferromanganese, as a reducer, is added to the tank at the very end of the steel smelting process before the steel is poured, it is clear that the phosphorus content in ferromanganese should not exceed established limits if the required special grades of steel are to be obtained. It is also necessary to bear in mind that the phosphorus is transmitted not only by the ores, but durimg smelting by the flux and coke cinders, which also must be of a certain standard.

The phosphorus content in ores is usually calculated not in absolute figures but in parts of 1 percent manganese.

It is self evident that if the ores are subjected to a concentration and during this process there is a partial reduction in phosphorus content, by the elimination of rock containing not any metal, as it is often the case, then the limits of acceptable phosphorus content (as well as other ore components) should be revised in evaluating the obtained concentrates.

With respect to the sulphur content in ores as a harmful ingredient, it is of no great importance in the smelting of manganese ores inasmuch as sulphur passes on easily to the slag in the form of MnS (Alabandite) and CaS (Olahamite).

If there is another harmful ingredient in the manganese ores -- arsenic -- (which is seldom the case) it volatilizes to an important degree with the escaping gases in the hot furnace, although some parts are retained in the pigs.

6. Sometimes alloys of useful metals may be found in the manganese ores, usually in insignificant quantities (cobalt, nickel,

vanadium) which are almost fully reducible. Only vanadium partly (up to 10-40 percent, depending upon the performance of the furnace) passes on to the slag. It should be borne in mind, in this connection, that the addition of ferromanganese, during the conversion of pig iron, is carried out in very small quantities. Therefore, the presence of these elements in manganese ores or in concentrates within the limits of a few hundredth or tenth parts of 1 percent will practically have no influence on the purity of the manufactured steels. This is also applicable to those manganese ores which are used as furnace charge in the production of ordinary pig iron.

If the ores contain copper, this also is completely reduced. Zinc partly passes on to the slag or is volatilized, and partly forms a crust. Lead accumulates on the bottom of the furnace and has a harmful influence on the layer, penetrating into the joints.

From the viewpoint of metallurgical economics, it is important that manganese ores and concentrates obtained from them should have a sufficiently high manganese content (or total manganese and iron), to be poor in silica and rich in alkaline earth components, and finally contain a minimum quantity of phosphorus.

The requirements which the metallurgical manganese ores must meet, depending on the purpose for which they are to be used, may be summed up as follows.

Ores for the Smelting of Ferromanganese

Ferromanganese of standard grades of all alloys of manganese and iron is of the greatest importance in the production of steel. A high manganese content in the alloys decreases the amount of ad-

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ditions and simplifies the process of steel production.

In accordance with the general standards of the Soviet Union (GOST 805-41) blast furnace ferromanganese is produced in 2 grades: FM-1, FM2, each one subdivided in classes A and B depending on the content in phosphorus (Table 6).

TABLE 6

ELEMENT CONTENT IN FERROMANGANESE ACCORDING TO

GOST 805-41

Grade	Element Content (in percent) Silicon	Manganese	Phosphorus Class A	Phosphorus Class B	Sulphur
FM-1	2.00	75.1 +	0.35	0.45	0.03
FM-2	2.00	70.0-75.0	0.35	0.45	0.03

In addition to the above cited grades of ferromanganese, non-standard grades of ferromanganese are produced from lower quality manganese ores containing 50-60-70 percent manganese and up to 0.6 to 0.8 percent phosphorus. These alloys are used to a large extent in the production of common grades of steel.

With respect to silicomanganese which is used in Western Europe as a reducer in the production of soft steels, no special grades have been established either in the USSR or in foreign countries. In foreign countries alloys have been made containing 55-75 percent manganese, 20-25 percent silica and 5-20 percent iron. As already indicated in the smelting of silicomanganese, although important quantities of silicon pass into the metal, the reduction of the manganese itself is appreciably increased. Because of this, the percentage content in phosphorus in the alloy is much lower than in ferromanganese produced from the same ores.

Considering the requirements of metallurgy and the chemical-mineralogical characteristics of common types of manganese and some iron-manganese ores, it is necessary to distinguish the following grades:

Grade I -- with a content in the raw ores or in the concentrates of over 40 percent manganese and under 15 percent of silica.

Grade II -- with a manganese content of 40-35 percent and silica 15-25 percent.

It is important to break down the ores of Grade I according to silica content: I-A with a content of SiO_2 up to 9 percent, and I-B with a content in SiO_2 of 9 to 15 percent.

The ratio of manganese to iron in the ores of type I-A should not be lower than 6-7 and for the ores of type I-B not lower than 8-10.

The phosphorus content of rich ores should not exceed 0.0030 to 0.0035 percent of 1 percent of manganese provided the smelting is done with coke of low phosphorus content. (At the end of the book a table of calculations will be found (see appendix II).) In the production of lower quality, non-standard grades of ferromanganese, if such are used in cases of necessity, the upper limit of phosphorus content may be increased to 0.0045 percent of 1 percent of manganese.

Thus, the classification of manganese ores (or concentrates) suitable for the production of ferromanganese generally may be summed up as follows (Table 7).

TABLE 7

REQUIREMENTS FOR MANGANESE ORES (AND CONCENTRATES)

SUITABLE FOR THE PRODUCTION OF FERROMANGANESE

Type	Mn	SiO_2	Mn: Fe	P
I-A	over 50%	up to 9%	not under 6-7	up to 0.17-0.20%
I-B	40-50	9-15	" " 7-10	" " 0.14-0.17
II	35-40	15-25	" " 3-4	" " 0.18
III	30-35	25-35	" " 4-5	" " 0.15

It is necessary to point out that the ores of Type I in the above classification are earmarked for the extraction of standard grades of ferromanganese. Ores of Types II and III are used for this purpose in cases of extreme necessity only, provided the iron and phosphorus (The ratio Mn: Fe should not be lower than 12-15 and the phosphorus content not over 0.0035 percent per 1 percent Mn.) content are very low. If this is not the case these ores may be used only as charge in the smelting of spiegel or converted and foundry pigs from iron ores. Ores with a high content of alkaline earths (oxides of calcium and magnesium) may be an exception to the rule.

Generally, it is necessary to emphasize that the presence of appreciable quantities of calcium and magnesium in manganese ore is extremely desirable as this will permit to decrease the addition of limestone and dolomite to the charge. It should not be forgotten that each 5 percent of calcium and magnesium oxides permit the use of ores with a silica content of 4 percent above the limit. Therefore, in sampling deposits it is necessary to test the content of calcium and magnesium oxides in the ores. It was already indicated that the best ores are self-fluxing ores rich in manganese and alkaline earths but poor in phosphorus, the content of which is not to exceed the above indicated limits. Such ores may be used in the production of standard grades of ferromanganese. The manganese content requirements for such ores may be lowered to 32 to 35 percent. Such are, for example, the ores of the Sapal deposits and some layers of silicate-carbonate ores of the USSR in deposits. Similar divergencies may be encountered among ordinary carbonaceous sedimentary ores rich in phosphorus.

For the production of silicomanganese, ores may be used that are hard to concentrate and are richer in silica than indicated for Types II and III. Therefore, the requirements for phosphorus content in ores are also lowered if the manganese reduction is high and in addition if an appreciable quantity of silica passes on to the metal. In such case, up to 0.006 percent of phosphorus per 1 percent of manganese may be acceptable.

Ores for the Smelting of Spiegel and Silicospiegel

These alloys are substitutes for ferromanganese in the production of a series of solid, medium and high carbon grades of steel. For this purpose, iron manganese ores are usually used.

Spiegel, depending on the manganese content, is produced in 3 grades, in accordance with the USSR standards:
Z-1 with a content of 20.1-25.0% manganese and 0.22 % phosphorus
Z-2 with a content of 15.1-20.0% manganese and 0.20 % phosphorus
Z-3 with a content of 10.0-15.0% manganese and 0.18 % phosphorus

Silicospiegel is produced in one grade S Sch-1 containing 18.0-24.0 percent manganese, 9.0-13.0 silica and 0.20 percent phosphorus.

In addition to these grades, the ferrous industry is using also non-standard grades of spiegel, particularly those richer in manganese but still limited as to their phosphorus content. Silicospiegel may be used with a lower content in silica (4-8 percent).

Spiegel is smelted from manganese ores rich in iron, from which standard ferromanganese cannot be obtained. The best ores are those containing highest quantities of manganese and iron and lowest quantities of phosphorus. Various grades of spiegel may be obtained depending on the ratio of manganese to iron in the ores. Priority is given to ores richer in manganese ores containing more silica which may be used for the production of silicospiegel.

Considering the composition of various types of Spiegel it is possible to give a general classification of grades of ferromanganese ores suitable for this purpose (Table 8).

TABLE 8

REQUIREMENTS FOR FERROMANGANESE ORES SUITABLE FOR THE PRODUCTION OF SPIEGEL AND SILICOSPIEGEL

Type	Mn+Fe	Mn:Fe	SiO_2	P
I	50-60%	1.5-0.6	up to 15%	up to 0.09-0.18%
II	40-50	2.0-0.8	15-25	0.08-0.15
III	30-40	2.5-1.0	25-35	0.07-0.12

As the ratio manganese to iron indicates, a wide range of variations in manganese content may be encountered in ores of this class. The best raw material is ores of Type I and II with an average manganese content not lower than 18-20 percent. The use of ores of Type III for the production of spiegel, particularly if they are rich in silica and poor in alkaline earths, should be undertaken only in cases of extreme necessity. This also applies to ores in Classes I and II poorest in manganese, particularly if they contain quantities of phosphorus above the specified limits. If this is the case, such ores as well as ores of Type III may be used only as a charge for the production of ordinary pigs.

Strict demands are made on ores as to phosphorus content. The limit content of this harmful element in ores destined for the melting of spiegel is established at 0.005 percent per 1 percent of manganese contained in ores. (Calculation tables on phosphorus content are given at the end of the book (see Appendix II).) This will explain the wide range of phosphorus variation, shown in Table 8, for each type of ore.

In nature, however, are encountered more often manganese ore deposits poor in iron which are not suitable for the production of ferromanganese, because their manganese content is not sufficiently high. Such ores, provided their phosphorus content falls within the limits, may be used for the production of spiegel and silicospiegel only with an appropriate addition of iron ores poor in phosphorus and iron and steel shavings. (In the production of steel, spiegel is to be fed in sizeable portions and therefore it is added in liquid form in order not to disturb the smelting process. For this purpose, special furnaces for the smelting of pigs are built in the steel plants called cupola furnaces.) As in all other cases, the ferromanganese ores rich in calcium are of particular interest and may often be found in carbonaceous varieties of ores.

With respect to ores suitable for the manufacture of spiegel, which is less essential to the ferrous metallurgy, the lack of extensive production experience in using them for this purposes does not yet permit to formulate special requirements for such ores. In general, however, such requirements coincide with those of raw mate- rials suitable for the production of spiegel except for the silica content which in this case is not harmful.

Ores for the Production of Manganese Pigs

For these purposes manganese iron ores are used. They are not widely found in nature. However, some known deposits contain rather important reserves of this type of raw material.

Manganese pigs containing 5-10 percent of manganese destined for the carburization and deoxidation of steel may be smelted from manganese iron ores for which ordinary requirements are:

a. Iron content should be 40 percent or over;

b. Manganese content -- 4 to 10 percent;

c. Phosphorus content -- not to exceed 0.05 percent in the ore.

The strict requirements with respect to phosphorus in ores are due to the fact that in steel production manganese pigs are fed into the furnace or ladle in important quantities at end of the smelting process. The phosphorus has no time to flux and is gen- erally absorbed by the steel.

Ores as Basic Fluxes for Steel Melting in Martin Furnaces

Rich in calcium manganese ores, which are seldom found in nature, are a very precious raw material for the ferrous metallur- gy (particularly ores poor in phosphorus) for various purposes: a. As tests have indicated, even with a low content of manganese (8-12 percent) they may, as fluxes, replace to a large extent ferromangan- ese in Martin furnaces; b. Mixed with iron ores or shavings, they may be utilized in blast furnaces for the production of spiegel, and they may be obtained from ores rich in silica-silicospiegel. In addition, their utilization as fluxes will probably make it possible to obtain ferromanganese from relatively poor silicomanganese ores, and also manganese pigs from iron ores.

The requirements for these types of ores are not yet worked out, but according to existing experiences rich in calcium ores with an 8-12 percent manganese content and about 0.005-0.006 percent phosphorus per 1 percent manganese are of definite industrial importance.

Recently carbonaceous ores poor in calcium (5-10 percent) and richer in manganese (up to 20 percent) were tested for this purpose at the Serov plant. It was determined that these ores, used in steel production in Martin furnaces, have a beneficial effect on the liquefaction of tough slags and at the same time permit a sharp reduction in the consumption of ferromanganese.

<u>Ores for Charges, in the Smelting of Ordinary Pigs from Iron Ores in Blast Furnaces</u>

As already mentioned, manganese and ferromanganese ores poor in manganese or rich in phosphorus are used for this purpose. The value of these ores is naturally appreciably lower compared with ores suitable for the production of the above mentioned special pigs.

If an iron ore contains close to 1.3 to 1.7 percent manganese, it may be used for the manufacture of converter pig without the addition of manganese ores. With some modifications, in connection with special processes of steel production, a manganese content in iron ores of 0.8 to 1.0 percent may be considered sufficient for the production of ferromanganese converter pigs with 0.6-0.8-1.0

percent Mn. However, inasmuch as the main operative deposits of iron ores contain a lesser quantity of manganese, it is necessary to add manganese to the furnace charge in the form of Martin slags and manganese ores, or only manganese ores and green slags (depending on the availability of such slags and the acceptable amount of phosphorus in the melted pigs).

Usually ores with a manganese content of 20-30 percent are used for this purpose. This content may be lowered to 10-15 percent provided it contains 15 percent or more iron. The general manganese content in the ore charge (including the manganese in the iron ore itself) should amount to 25-30 kilograms for each ton of pig.

An iron content in these ores is generally desirable, the more iron, the better.

The requirements relative to phosphorus are lowered compared with the requirements on ores used for the smelting of special pigs inasmuch as the manganese added to the charge is fed to the furnace in loads and in the ore smelting process the phosphorus may be fluxed. The acceptable phosphorus content in manganese ores for these purposes is up to 0.3 percent.

A high silica content is not desirable since its scorification not only requires additional quantities of limestone, but also requires an additional expenditure in coke which lowers the productivity of the blast furnaces. The desirable silica content in manganese ores added to the charge should not exceed 35 percent but in case of necessity it may be acceptable at 45-50 percent. Ores with a high silica content are used in the smelting of foundry pigs.

II. PHYSICAL REQUIREMENTS FOR ORES

The requirements as to the chemical composition of manganese ores were laid down above. However, the physical properties also are of great importance.

The most desirable for the ferrous industry are hard ores, which do not have to be concentrated and which during processing give lumps not containing small particles. Such ores can be easily transported and do not have any large losses during strong blasting in large blast furnaces. The loading weight also depends on the size of the ore lumps which is of importance to the ore transportation. Therefore, in surveys it is necessary to establish the characteristics of ores according to the size of the material. If the ores contain important quantities of small particles (under 5 millimeters) it is desirable to sift the ores in order that the smaller parts may be compressed into bricks or agglomerated, or used in the chemical industry.

Large pieces of manganese ore are crushed on the ore yards near the blast furnaces into morsels of 50 to 70 millimeters in order to create more fa v orable conditions for the reduction of the ore mass. In surveying new deposits it is extremely desirable to indicate the degree of friability of the ores, resistance to pressure and other mechanical properties which are important for the organizations planning and designing projects, concentration, and metallurgical plants. It is desirable that the resistance of the lumps to pressure should not be under 60 kilograms per square centimeter.

Ores are subjected to concentration in cases where it is necessary to increase their quality, in particular, to increase the metal content and eliminate the parts not containing metal or reduce the content of harmful admixtures. For manganese ores, as is also the case for all other useful ores, the beneficiation process depends largely on the physical properties and in particular on the structure and texture of the ores. As is known, the texture and structure of the ore components determine the necessary degree of crushing. Therefore, in surveying deposits, special attention should be given to the formation characteristics of the various types of ores and an approximate calculation should be made on the quantitative importance of the texture of the ore components. This applies particularly to ores composed of oolite-like concretions, ores in their layers, etc.

Inasmuch as the products resulting from the concentration of manganese ores are chiefly fed into blast furnaces, it is natural that attempts are made to employ ordinary and comparatively cheap ore concentration methods such as sifting or washing of the ores, and in the case of preliminary crushing concentration is done by jigging machines in order to obtain a maximum number of large size classes (over 5 millimeters) of preliminary concentrates. However, if the ore is subjected to a satisfactory preliminary concentration, an ore deposit with particle size of under 5 millimeters may be considered of industrial value, provided there are large reserves of it which will insure the work of the concentration plant for a definite amortizable period and under favorable economic regional prerequisites.

Expensive concentration methods of fine milling and grinding of the ore and subsequent flotation are used in exceptional cases, when the deposit is large or the ore cannot be subjected to a suitable preliminary concentration by any other method. True, the powder-like concentrate obtained by this method is of high quality but it absolutely requires pressing into bricks and agglomeration. It is desirable to prepare an agglomerate of a self-fluxing composition and add, in addition to coke, the necessary quantities of calcium-containing materials.

The porosity of the texture components (oolites, concretions, ore layers, etc) indicates, on the one hand, a positive, and on the other hand, a negative influence on theproperties of manganese ores.

The importance of the porosity of ore components is such that it is strongly reflected on the degree of reduction of manganese oxides and, consequently, on the efficiency of the blast furnace, the time required for the processing of a charge, and fuel expenditure. The water containing pyrolusite-psilomelane ores, namely, the primary oxides of young precipitation-deposits as well as ores of manganese hats have the greatest porosity (Tchiatoursk, Polounotch and other regions). The anhydrous hydrometallic and metamorphogenic deposits have the lowest ore component, porosity (deposits of Sapal, Central Khazakstan, etc). Therefore, they are much harder to reduce.

On the other hand, the porosity of the ore greatly increases its capacity to absorb water. The moisture content of such ores often reaches 12-15 percent and in some types of ores of the Tchiatur deposits it reaches 18-25 percent. It is self-evident that this is of great importance in the transportation of the ores. A high degree of moisture content increases appreciably the weight of the material per cubic meter of ore, consequently, the freight expenses. In addition, the high moisture content of ore deposits located in the northern latitudes causes them during the winter to freeze and stick to the walls of the storage bins. Moisture also affects the normal loading of the blast furnace which must work at a low production rate.

In addition to absorbed water (moisture) the ores may also contain water, chemically combined with some minerals (manganite, psilomelane, vermadite and others). This water may be removed by heating to 110 degrees Centigrade. In the process of heating in the blast furnaces the loss of such water sharply increases porosity and consequently the specific surface. This increases the reduction speed of manganese oxides. From this point of view the anhydrous braunite-hausmannite ores, having lower qualities, have to be crushed in order to increase the specific surface, which results in agglomeration.

The thermal stability of ores, that is, ability to remain in lumps at high temperatures, also influences the efficiency of the blast furnace. More or less compact oxide and hydro-oxide manganese ores usually withstand high temperatures. Only soft, moist ores dry out and crumble in the heating process. This causes high losses during strong blasting, not to mention that a large amount of small particles strongly affects the gas permeability of the charge by creating at the blasting places passages for the non-productive stream of gases and by clogging in other places the spaces between the lumps of the charge. With respect to carbonaceous ores, these ores are subject to strong cracking-up and ~~crumbling at~~ high temperatures as a result of the dissociation of carbon and large liberation of carbon dioxide. In some cases, where it is necessary to resort to preliminary oxidizing burning, the pure carbonaceous ores practically lose their lumpiness or the strength of the lumps themselves is sharply weakened if admixtures of binding substances are not used. Only the opale-carbonaceous manganese ores do not change appreciably their lumpiness during burning. The cracking of carbonaceous manganese ores at high temperatures must not be considered as an adverse factor of blast furnace efficiency since the dissociation of carbonates is carried out at high temperatures (700-800 degrees Centigrade, judging by the temperature recorders). On the contrary, when using manganese limestone and calcium-manganese ores as basic flux in the Martin furnace, the cracking up and pulverization of the carbonaceous substance at places of contact with the melted metal is an extremely favorable factor contributing to the reduction of manganese ore to metal.

The clinkering capacity, i.e., the ability of the mineral powdered substances to form during burning nodulizing combinations with manganese ores, represented by hydrous-oxides (psillomelane-pyrolusite and manganite varieties), is found to vary considerably. Ores represented by anhydrous minerals (braunite, hausmannite) do not have these properties at all. Clinkering experiments made at the Magnitogorsk Plant on ores of the Tchiatur region indicated that, although the clinkering action is not normal (because of the lump part), the obtained agglomerate, however, is sufficiently strong. Thanks to the elimination of appreciable quantities of combined water and parts of oxygen (from the dissociation of pyrolusite) the porosity and, consequently, the degree of reduction of the agglomerated ore should increase sharply. The preparations of self-fluxing agglomerates is, of course, the most rational, i.e., with admixture of fuel and slag components.

B. Chemical Ores

In the chemical industry manganese ores are used for various purposes in the production of dry electric batteries, in the preparation for the same purpose of articifially activated products from pyrolusite ores, in the glass industry for the discoloration of green glass, in the production of chemical preparations used in medicine, in the preparation of special anti-gases for protection against carbon oxides, catalysts of the hopealite type for the cleaning of automobile engines from harmful admixtures in the exhaust gases, in the production of drying oil, grease, wax, in the production of chrome leather, in photography, preparation of paints for porcelain and glazed pottery, in the production of bromine, iodine, etc.

For industrial chemical uses, particularly for the production of dry electric cells, only those of the numerous manganese minerals are of importance which contain manganese dioxide in the largest quantity. Such minerals include: pyrolusite minerals, of the psilomelane and venanzite groups. The remaining hydrous oxides and oxides of manganese (manganite, braunite, hausmannite and others) are less important for such purposes.

Among the manganese deposits containing ores rich in 4-valence manganese, suitable for the chemical industry, of most importance are the comparatively young sedimentary, stratified deposits (of the Tchiatur deposit type) and the oxidization zones of the deposits, regardless of their genetic type. For these industries in which the superficial energy of the mass is used, the fully oxidized manganese ores are particularly valuable (in particular the so-called black belts of the Tchiatur deposits), having an ~~unusually~~ thin covered crystalline porous mass of pyrolusite of low consistency.

Of all the above named chemical uses the production of dry-cells assumed the greatest importance in the past 25 years, especially in connection with the development of radio technology. Tests carried out in the past years have shown that the content in MnO_2 in the ore used for these purposes is not critically important as the depolarization depends on the decomposition speed of the manganese dioxide which, apparently, is related to the degree of dispersion of the material used.

Pyrolusite ores are used advantageously for these purposes. The requirements for ores used in the production of dry electric batteries are generally as follows:

1. The content of manganese dioxide is not to be lower than 80 percent, i.e., in terms of metallic manganese content not under 50 percent;

2. Iron content is not to exceed 3 percent;

3. Calcium is acceptable up to 2-3 percent;

4. Soluble combinations of cobalt, nickel and arsenic are considered as extremely harmful elements and only traces of these elements are acceptable.

5. Copper content is not to exceed 0.2 percent.

Silica and phosphorus have no substantial importance. Similarly, there are no special requirements as to the physical properties of the ores. For this purpose small grain concentrates, which are sometimes obtained in important quantities during the concentration of metallic ores, may also be used successfully.